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Predicting statistical parameters for UHF and microwave propagation in cities for advanced spread spectrum design

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6. AUTHOR(S)
I-Tai Lu and Henry Bertoni

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Polytechnic University
901 Route 110, Farmingdale, Ny 11735

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13. ABSTRACT (Maximum 200 words)
Our research objective is to develop efficient algorithms for predicting statistical parameters for UHF and microwave propagation cities for advanced spread spectrum {systems}. In the first year, we have studied the mechanisms contributing to angular spread at base station. We have also developed a ray formalism for modeling propagation in city streets which contain cars, trees and other scatters. In the second year, simulations of delay spread and angle spread have been carried out using the VPL ray tracing tool in rise and mixed height building environments. Range dependence and shadow fading for residential environments has been simulat for frequencies ranging from 30 MHz to 3 GHz. In addition, we have developed a multiple antenna systems to increase channel capacity greatly by taking advantages of the multipath propagation characteristics. In the third year, {the} VPL code {wass} used evaluation of higher order channel statistics and for the optimization of the mobile assisted hard and soft handoff algorithm parameters. The propagation parameters such as the shadow fading standard deviation and the cross-correlation are shown to influ the performance of handoff algorithms. Analysis of foliage effects on RF propagation in urban environments was also performed.

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Sincerely,

I-Tai Lu

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(Continuation Sheet)

(4) Statement of the problem studied

The ability to understand and to predict the RF propagation and scattering effects is crucial to modern wireless communications for military applications. In most battlefield situations only limited environmental information is available, yet various key propagation parameters have to be urgently assessed. Unfortunately, the existing two modeling techniques (statistical and deterministic) are inadequate to address the dynamic heterogeneous environments of wireless communications for the US Army. To take advantages of each of the two techniques, we have developed hybrid statistical-deterministic approaches for analyzing RF propagation in urban environments. We have also study various higher order statistics of propagation characteristics and their effects on modern communication technologies and systems.

(5) Summary of the most important results

Many results have been derived in the last three years. Listed below are the brief descriptions of these results.

(a) Propagation Modeling:

(i) VPL Ray Tracing Code

We have made algorithmic improvements in the VPL code, and have assessed the improvement in accuracy of the predictions. One group of improvements involves the use of a better heuristic diffraction coefficient for dielectric wedges, and a better treatment of multiple diffractions over buildings. These changes appear to give higher predictions in the deep shadow regions, where the original predictions were low. A more fundamental code improvement is inclusion of diffuse scattering from building surfaces. Assuming Lambert's law for the scattering, the inclusion of diffuse scattering appears to reduce the RMS error of the predictions by one or two dB. The scattering from buildings has been studied to find a more accurate scattering law.

(ii) Statistical Propagation Modeling Technique

We have also developed a new statistical propagation modeling technique for urban environments. We have modeled the city street as a plane parallel waveguide with randomly displaced boundaries and a variable random reflection coefficient. Expressing the statistical propagation characteristics in terms of multiple reflected and/or diffracted ray-fields approaching the observer, we present the analysis of the fluctuation effects caused by random displacements of the building boundaries. Further, we extend the ray formalism to propagation in city streets that contain cars, trees and other scatters. These scattering effects can be incorporated into the ray model by adopting the methods developed in the Stochastic Geometrical Theory of Diffraction. This allows us to present analytical expressions for the statistical field measures and to analyze the fading effects.

(b) Statistical Properties Of Propagation In Urban Environments

(i) Delay Spread And Angle Spread

We have simulated delay spread and angle spread statistics in Rosslyn, VA, Seoul, Korea and Munich, Germany for many mobile locations and various base station antennas heights and locations. The delay spread was found to be in good agreement with a measurement base model that indicates delay spread to be approximately a lognormal random variable whose median increases as the square root of the distance. Angle spread is also approximated by a lognormal random variable, but it has irregular distance dependence. Sensitivity studies show that the predictions of delay and spread statistics are not significantly changed by random errors is computing the amplitude and delay of individual rays, so that the results are not effected by the levels of error found in the ray code predictions of amplitude. We have shown that the mechanisms contributing to angular spread at a base station are diffuse scattering from the building near the mobile, and reflection and diffraction around building of irregular height. Simulations based on the latter effect show agreements with measured results. The simulations can be used to compare different cities, and to investigate dependence on parameters, such as antenna height.

(ii) Range Dependence And Shadow Fading

Range dependence and shadow fading for residential environments has been simulated for frequencies ranging from 30 MHz to 3 GHz base on a simplified model of low buildings that are organized in rows along the streets. The model, which accounts for transmission through the buildings at the lower frequencies, is a generalization of knife edge model previously employed for frequencies in the range of 1 GHz. Good agreement has been found with the limited data for low frequencies published in the literature.

(iii) Cluster Effects

In CDMA systems, the rake receiver can separately detect individual clusters of arrivals. Within a cluster, the relative delay of the arrivals is small, and cannot be resolved by the receiver. However, different clusters are separated by a relative time delay that is large enough to be resolved. Individual clusters may be acquired and detected by the rake receiver. As a receiver travels along a road, individual clusters may increase or decrease in amplitude as result of shadowing by buildings along the path. The receiver design requires knowledge of the duration of time that second or third clusters are large enough for reception. We have simulated the distance along streets where more than one cluster is strong enough for reception. Median distances are found to range from 15 - 70 m, depending on the base station location and city. We are currently seeking to compare this result with measurements. We have analyzed measurements made in Helsinki to extract distances along streets for multiple cluster reception and found agreement with the simulations.

(c) Propagation Characteristics and System Performances

(i) Mobility Effects on the Routing and Medium Access of Wireless Ad hoc Network

We have developed a bandwidth efficient approach to accommodate the changing topology in mobile ad hoc networks. The protocol exhibits both hierarchical and peer-to peer characteristics. The hierarchical feature improves efficiency and the peer-to-peer feature mitigates traffic bottlenecks.

(ii) Effects of Auto and Cross Correlations of Shadow Fading On Hand off Performances

The effect of cross-correlation of shadow fading signals on the selection of optimum handoff parameters is analyzed. A large hysteresis in highly correlated situations results in a long handoff delay, while a small hysteresis in uncorrelated situations causes the ping-pong effect. A sufficiently long averaging length reduces the error in estimating an appropriate hysteresis. Too long of an averaging length, especially when the threshold is low, may result in a large handoff delay.

(iii) Effects of Multipath Propagation on Smart Antenna Systems

Multiple antenna systems have been developed using both transmit and receive smart antennas to establish multiple communication channels in the same time and bandwidth between two localized transceivers. By taking advantages of the multipath propagation feature, optimum weights of smart antennas at both transmitter and receiver are determined by novel hybrid approaches combining pre-processing and post-processing approaches for both narrowband and broadband systems. Large signal to interference and noise ratios and low bit error rates are obtained for practical non-stationary time division duplex as well as frequency division duplex wireless communication systems. The primary merit of this new multiple antenna system is that the channel capacity increases linearly with the number of antenna elements.

(6) Listing of all publications and technical reports

(a) Papers published in peer-reviewed journals:

1. C. M. Qiu and I. T. Lu, "Multipath resolving with frequency dependence for roadband wireless channel modeling," IEEE Trans. Veh. Techno., Vol. 48, No. 1, 273-285, 1999.

2. Mario Joa-Ng and I.T. Lu, "A novel spread spectrum based synchronization and location determination method for wireless system," IEEE Communications Letter, Vol.3, No. 6, June 1999, 177-179.

3. Mario Joa-Ng and I.T. Lu, " A peer-to-peer two-level link state routing for mobile ad-hoc wireless network," the special issue on Wireless Ad Hoc Networks of IEEE JSAC, Vol. 17, No. 8, Aug. 1999.

4. Reuven Mazar, Alexander Bronshtein and I-Tai Lu, "Analysis of foliage effects on mobile propagation in dense urban environments" Radio Sci. 35 (4), 941-954, (2000).

(b) Papers published in non-peer-reviewed journals or in conference proceedings

1. H. L. Bertoni, P. Pongsilamanee, C. Cheon and G. Liang, "Sources and Statistics of Multipath Arrivals at Elevated Base station Antennas," Proceedings of the IEEE Vehicular Technology Conference, Houston, TX, May, 1999.

2. Mario Joa-Ng and I-Tai Lu, "Spread Spectrum Medium Access Protocol with Collision avoidance in Mobile Ad-hoc Wireless Network," INFOCOM'99, New York.

3. J. Choi and I-Tai Lu ,"Space-Time Processing for Broadband Multi-channel Communication Systems Using Smart Antennas at Both Transmitter and Receiver," ICC'99, Vancouver B.C., Canada.

4. J. Choi and _I-Tai Lu ,"Broadband Smart Antenna Technique for Both Transmitter and Receiver with Multiple Access Interference Cancellation," IEEE VTC'99, Houston, Tx.

5._I-Tai Lu and J. Choi,"Multiple Access Smart Antenna Processing Techniques for Both Time and Frequency Duplex Communication Systems," IEEE VTC'99, Houston, Tx.

6. I-Tai Lu and Joon-Sang Choi "Sensitivity Study of Smart Antenna Systems with both Transmission and Reception Diversities" Milicom99, Atlantic City, NJ

7. J. Kwak and I-Tai Lu,"Blind Adaptive Space-Time Receiving and Transmitting Diversites for Multiuser CDMA systems" Milicom99, Atlantic City, NJ

8. J. Kwak and I-Tai Lu,"Adaptive Blind MIMO Channel Estimation and Multiuser Detection in DS-CDMA Systems" GLOBECOM'99, Rio Brazil

9. C. Cheon, H.L. Bertoni and G. Liang, "Monte Carlo Simulation of Delay and Angle Spread in Different Building Environments," Proceedings of the IEEE Vehicular Technology Conference, Boston, MA; September, 2000.

10. Mario Joa-Ng and I.T. Lu, " A new zone-based hierarchical link state routing for mobile ad-hoc wireless network," to be presented in IEEE VTC2000, Tokyo, Japan.

11. Sung Jin Hong and I-Tai Lu, "Effect of Various Threshold Settings on Soft Handoff Performance in Various Propagation Environments," IEEE VTC 2000 Fall, Boston MA, September 24-28, 2000

12. Sung Jin Hong and I-Tai Lu, "Performance of Soft Handoff Algorithms in Various Propagation Environments," IEEE ISSSTA 2000 (6th International Symposium on Spread Spectrum Techniques and Applications), Parsippany NJ, September 6-8, 2000

13. Sung Jin Hong and I-Tai Lu, "Effect of Various Threshold Settings on Soft Handoff Algorithm Performance," IEEE RAWCON 2000 (Radio and Wireless Conference, Denver CO, September 11-13, 2000

14. Wearn-Juhn Wang, I-Tai Lu and Shang-Chieh Liu, "SOFT HANDOFF PERFORMANCES OF 3-SECTOR and 6-SECTOR MULTICELL CDMA SYSTEMS," IEEE VTC2001 Spring, May 6-9, 2001, RRhodes, Greece.

15. Wearn-Juhn Wang, I-Tai Lu and Shang-Chieh Liu, "Soft Handoff Analysis of CDMA Systems Using Novel Switched-Beam Smart Antennas with Polarization Diversity,"IEEE VTC2001 Spring, May 6-9, 2001, RRhodes, Greece.

(c) Papers presented at meetings, but not published in conference proceedings

1. Reuven Mazar, Alexander Bronshtein and I-Tai Lu, "Fluctuation Effects in Microwave Mobile Communication Channel," URSI, Toronto, Aug. 1999.

2. C. Cheon, H. L. Bertoni and G. Liang, "Simulating Radio Channel Statisticsfor Different Building Environments," National Radio Science Meeting, Boulder, CO; January 4-8, 2000.

3. C. Cheon, H. L. Bertoni and G. Liang, "Simulating Radio Channel Statisticsfor Different Building Environments," National Radio Science Meeting, Boulder, CO; January 4-8, 2000.

4. I-Tai Lu, Wearn-Juhn and Henry Bertoni, "Matrix Channel Modeling and Equalization for Multiple Transmit and Receive Antennas," National Radio Science Meeting, URSI Boulder, CO; Jan. 2001.

5. I-Tai Lu, Byung-Chul Kim and Henry Bertoni, "Physics-based Ultra-Wideband Channel Simulator," National Radio Science Meeting, URSI Boulder, CO; Jan. 2001.

6. I-Tai Lu, Wearn-Juhn and Sung Jin Hong, "Propagation Modeling for Handoff Analysis in Advanced Cellular Systems using Smart Antennas," National Radio Science Meeting, URSI Boulder, CO; Jan. 2001.

(d) Manuscripts submitted, but not published

1. H. K. Chung and H.L. Bertoni, "Range Dependent Path Loss Model in Residential Areas for the VHF and UHF Bands," IEEE Transactions on Vehicular Antennas and Propagation; accepted for publication.

2. C. Cheon, G. Liang and H. L. Bertoni, "Simulation of the Dependence of Delay and Angle Spread Statistics on Building Environment and Path Geometry," IEEE, Journal on Selected Areas in Communications, accepted for publication.

3. Sung Jin Hong and I-Tai Lu, "Effect of Cross-Correlation of Shadow Fading Signals on the Selection of Soft and Softer Handoff Parameters in CDMA Systems," IEEE Trans. on Vehicular Technology: in review.

4. H.M. El-Sallabi, G. Liang, H.L. Bertoni and P. Vainikainen, "Invluence of Diffraction Coefficient and Database on Ray Prediction of Power and Delay Spread in Urban Microcells," IEEE Trans. on Antennas and Prop.: in review.

5. H.M. El-Sallabi, H.L. Bertoni and P. Vainikainen, "Iexperimental Evaluation of Rake Finger Life Distance for CDMA Systems," IEEE Antennas and Wireless Propagation Letters, in review.

(7) List of all participating scientific personnel showing any advanced degrees earned by them while employed on the project

1. Mario Joa Ng, "Routing Protocol And Medium Access Protocol For Mobile Ad Hoc Networks," Dissertation in partial fulfillment of the requirements for the PhD in Electrical Engineering at Polytechnic University, June 1999.

2. Jaeyoung Kwak, "Novel Blind Adaptive Space-Time Multiuser Detection Schemes For Both Uplink And Downlink," Dissertation in partial fulfillment of the requirements for the PhD in Electrical Engineering at Polytechnic University, June 1999.

C. H. Cheon, "Simulating Radio Channel Statistics in Urban Environments," Dissertation in partial fulfillment of the requirements for the PhD in Electrical Engineering at Polytechnic University, August 2000.

4. S. J. Hong, "Performances of handoff algorithms in various cellular systems environments," Dissertation in partial fulfillment of the requirements for the PhD in Electrical Engineering at Polytechnic University, August 2000.

5. H. K. Chung, "Radio Channel Studies from 30 MHz to 5 GHz," Dissertation in partial fulfillment of the requirements for the PhD in Electrical Engineering at Polytechnic University, December 2000.